

PATENT ABSTRACTS OF JAPAN

(11)Publication number : 09-243909

(43)Date of publication of application : 19.09.1997

(51)Int.Cl. G02B 13/18

G02B 27/64

G03B 5/00

G03B 17/00

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(54)CAMERA SHAKE CORRECTION OPTICAL SYSTEM

(57)Abstract:

PROBLEM TO BE SOLVED: To provide a correction optical system restraining the deterioration of performance for camera shake correction to a minimum and easily positionally adjusting an image-formation optical system.

SOLUTION: This optical system A1 is arranged in front of an image formation optical system A2 and constituted of a fixed biconcave single lens A1a and a movable biconvex single lens A1b in order from an object side. At least one of the respective surfaces of the lenses A1a and A1b is in aspherical shape having the radius of curvature and aspherical degree within a specified range, and the lens A1b is moved in a direction orthogonal to the optical axis direction L-L of an entire optical system to correct the camera shake.

LEGAL STATUS [Date of request for examination]

[Date of sending the examiner's decision of rejection]

[Kind of final disposal of application other than the examiner's decision of rejection or application converted registration]

[Date of final disposal for application]

[Patent number]

[Date of registration]

[Number of appeal against examiner's decision of rejection]

[Date of requesting appeal against examiner's decision of rejection]

[Date of extinction of right]

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CLAIMS

[Claim(s)]

[Claim 1] It is arranged ahead of image formation optical system. Both the concave single lens of immobilization in the order from a body side, Consist of both the movable convex single lens, and the at least 1st of each sides of said fixed lens and a moving lens is made into the aspheric surface configurations of the radius of curvature of predetermined within the limits, and the amount of aspheric surfaces. Hand deflection amendment optical system characterized by having the afocal optical system which is made to move said moving lens in the direction which intersects perpendicularly to the direction of an optical axis of all optical system, and amends a hand deflection.

[Claim 2] Hand deflection amendment optical system according to claim 1 with which said fixed lens and moving lens filled the following conditions.

[Equation 10]

$$0.1 < | r_2 / r_1 | < 0.75$$

[Equation 11]

$$0.1 < | r_3 / r_4 | < 0.75$$

[Equation 12]

$$1.0 \times 10^{-3} < | \Delta x_1 / r_{asp1} | < 5.0 \times 10^{-3}$$

[Equation 13]

$$0.5 \times 10^{-3} < | \Delta x_2 / r_{asp2} | < 5.0 \times 10^{-3}$$

radius-of-curvature r_3 : of the field by the side of the image of the
radius-of-curvature r_2 :fixed lens of the field by the side of the body of an r_1 :fixed lens
-- radius-of-curvature r_4 : of the field by the side of the body of a moving lens --
paraxial radius-of-curvature Δx_2 : of the aspheric surface of the amount r_{asp} of
aspheric surfaces 1:fixed lens of the radius-of-curvature Δx_1 :fixed lens of the field
by the side of the image of a moving lens -- amount r_{asp} of aspheric surfaces 2: of a
moving lens -- the paraxial radius of curvature of the aspheric surface of a moving
lens

DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Field of the Invention] This invention relates to the hand deflection amendment optical system which amends a hand deflection by moving the moving lens which constitutes the afocal optical system arranged ahead of image formation optical system in the direction which intersects perpendicularly to the optical axis of all optical system.

[0002]

[Description of the Prior Art] For example, since it is lightweight and easy to produce a hand deflection at the time of photography, when the image photoed especially by zoom-in is reproduced, big image Bure generates the video camera of a pocket mold etc. Then, the various proposals of the equipment which amends the hand deflection at the time of photography are made. For example, a sensor detects a motion of the body of the video camera by the hand deflection etc., a part of optical system is

moved, a hand deflection is amended, and the equipment which lost image Bure is known. This hand deflection compensator is equipped with the image formation optical system by which the 1st group of immobilization among variable power, the variable power group, and the fixed group (the lens for a focus is included) have been arranged in this order from the body side. The hand deflection according to the inclination of image formation-optical-system can be amended by arranging before such image formation optical system, and moving some of the lenses in the direction which intersects perpendicularly to the optical axis of joint optical system.

[0003]

[Problem(s) to be Solved by the Invention] If it was in the optical system which amends the conventional hand deflection mentioned above, since some lenses which participate in image formation were moved as a movable group and the hand deflection was amended, there was a problem that the performance degradation of hand deflection amendment was large. Moreover, in the condition of not performing hand deflection amendment, it faced positioning a movable group in the location of normal, and was obliged to justification of image formation optical system, and there was also a problem that tuning became difficult.

[0004] In view of the above point, the performance degradation of hand deflection amendment is small, and this invention aims to let it for justification of image formation optical system offer easy hand deflection amendment optical system.

[0005]

[Means for Solving the Problem] According to this invention, the above-mentioned purpose is arranged ahead of image formation optical system. Both the concave single lens of immobilization in the order from a body side, Consist of both the movable convex single lens, and the at least 1st of each sides of said fixed lens and a moving lens is made into the aspheric surface configurations of the radius of curvature of predetermined within the limits, and the amount of aspheric surfaces. It is attained by having the afocal optical system which is made to move said moving lens in the direction which intersects perpendicularly to the direction of an optical axis of all optical system, and amends a hand deflection.

[0006] Since the optical system which participates in image formation is not moved at the time of hand deflection amendment according to the above-mentioned configuration, performance degradation at the time of hand deflection amendment can be made small. Moreover, since the afocal hand deflection amendment optical system with which it participates in hand deflection amendment, and the image formation optical system which participates in image formation can be dealt with as a separate module, justification of image formation optical system can be made easy.

[0007]

[Embodiment of the Invention] Hereafter, the suitable operation gestalt of this invention is explained to a detail, referring to an attached drawing. In addition, since

the gestalt of the operation described below is the suitable example of this invention, desirable various limitation is attached technically, but especially the range of this invention is not restricted to these gestalten, as long as there is no publication of the purport which limits this invention in the following explanation.

[0008] Drawing 1 is drawing showing the basic configuration of all optical system including the operation gestalt of the hand deflection amendment optical system of this invention. The hand deflection amendment optical system A1 and the image formation optical system A2 of arbitration are arranged sequentially from the body side. This hand deflection amendment optical system A1 is constituted by lens A1a of the immobilization which is the aspheric surface single lens of both concaves sequentially from a body side, and movable lens A1b which is the aspheric surface single lens of both convexes.

[0009] In such a configuration, it is moved in the direction in which moving lens A1b arranged behind fixed lens A1a intersects perpendicularly to optical-axis L-L of all optical system by the lens mechanical component LD, and a location is controlled. In addition, although illustration is omitted, after a sensor's detecting pitching and rolling of all optical system, for example and processing the output signal by control sections, such as a microcomputer, as a control system which detects the inclination of all optical system and controls migration of moving lens A1b, there are some which carry out hand deflection amendment by sending out a control signal to the lens mechanical component LD.

[0010] Drawing 2 is a principle Fig. about the hand deflection amendment optical system A1 in a paraxial field. The fixed lens If shown in this drawing is equivalent to the above-mentioned fixed lens A1a, and a moving lens Im is equivalent to the above-mentioned moving lens A1b. Among this drawing, Point Fm shows the focus by the side of the body of a moving lens Im, and Point Ff shows the focus by the side of the body of the fixed lens If. Moreover, a beam of light Ry1 passes along the principal point of the fixed lens If, after passing along the focus Fm of a moving lens Im, it shows the beam of light which finally advances in parallel with optical-axis L-L of all optical system, and shows the beam of light which as for a beam of light Ry2 advances so that it may be in agreement with optical-axis L-L, after the incident angle to the hand deflection amendment optical system A1 is made equal to a beam of light Ry1 and passes along the hand deflection amendment optical system A1. In addition, R-R shows the optical axis of a moving lens Im. Therefore, the relation which shows the incident angle to the hand deflection amendment optical system A1 of the flux of light which goes the movement magnitude of the moving lens Im to the direction which intersects perpendicularly to optical-axis L-L to sla and a photograph center to several 1 when the focal distance of $\Delta\theta$ and the fixed lens If is set to fl_a is materialized.

[Equation 1]

$$s l a = f l a \cdot \tan (\Delta \theta)$$

[0011] As shown in several 1, the movement magnitude sla of the moving lens Im required to amend the inclination of all optical system will be prescribed by only the focal distance fla of the fixed lens If. By the way, the scale factor M of the hand deflection amendment optical system A1 is expressed with several 2 when the focal distance of a moving lens Im is set to flb.

[Equation 2]

$$M = - f l a / f l b$$

Therefore, incident angle deltatheta to the hand deflection amendment optical system A1 of the flux of light which goes to the inclination of all the optical system by the hand deflection, i.e., a photograph center, first, Since the focal distance fla of the fixed lens If can be set up from relation (several 1 reference) with the movement magnitude sla of a moving lens Im, next the focal distance flb of a moving lens Im can be set up from the scale factor M of the hand deflection amendment optical system A1 (several 2 reference) The degree of freedom about a setup of the movement magnitude sla of a moving lens Im is large. Furthermore, since only the hand deflection amendment optical system A1 can be taken out and the physical relationship between the fixed lens If and a moving lens Im can be set up with a sufficient precision using an autocollimation method, simplification of an adjustment device and shortening of adjustment time amount can be attained.

[0012] As mentioned above, since the hand deflection amendment optical system A1 and the image formation optical system A2 can be independently designed, respectively by arranging the hand deflection amendment optical system A1 which is afocal ahead of the image formation optical system A2 of arbitration, and has the function of hand deflection amendment, a design becomes easy. Moreover, in order to amend a hand deflection in the hand deflection amendment optical system A1 most located in a body side, the relation between inclination deltatheta of all optical system and the movement magnitude sla of a moving lens Im turns into relation fixed regardless of variable power, and the configuration of the control system for controlling the location of a moving lens Im becomes easy.

[0013] It is as follows when conditions for amendment of the hand deflection over a screen size to become effective here are searched for. The relation between inclination deltatheta of all optical system and amount of Bure deltaY of an image is expressed with several 3 when the focal distance of all optical system is set to f.

[Equation 3]

$$\Delta Y = f \cdot \tan (\Delta \theta)$$

In variable power optical system, since a focal distance f changes, even when inclination $\delta\theta$ of all optical system is fixed, amount of Bure δY of an image changes, and image Bure is most conspicuous in a tele edge.

[0014] From several 1 and several 3, amount of Bure δY_{max} of the image which can be amended is expressed with a-four number, when the maximum movement magnitude of a moving lens l_m is set to $s l_{max}$ and the focal distance in the tele edge of all optical system is set to f_t .

[Equation 4]

$$\Delta Y_{max} = s l_{max} \cdot f_t / f_l a$$

Several 5 will be obtained, if one half of the die length of the diagonal top of a screen size is set to h_i and several 4 both sides are broken by this h_i , respectively.

[Equation 5]

$$\Delta Y_{max} / h_i = s l_{max} \cdot f_t / f_l a / h_i$$

It is the ratio which shows what image of amendment of amount of Bure δY is possible to one half of the die length h_i of this diagonal top of several 5 screen size, and in order to acquire the effectiveness of hand deflection amendment, it is desirable to fulfill the conditions shown in several 6.

[Equation 6]

$$0.2 < | f_t \cdot s l_{max} / f_l a / h_i | < 2.0$$

In several 6, since the hand deflection amendment optical system A1 needs to cover a large field angle if the effectiveness of hand deflection amendment will become small, the problem of degradation will remain, if the value of a ratio is less than a lower limit 0.2, and the value of a ratio exceeds an upper limit 2.0, problems, such as causing enlargement and lens performance degradation of a lens, arise.

[0015] Next, the proper conditions about the scale factor M of the hand deflection amendment optical system A1 are explained. Since it has the composition that the hand deflection amendment optical system A1 was added ahead of the image formation optical system A2, the focal distance f of all optical system is expressed with several 7 using the scale factor M of the hand deflection amendment optical system A1, and the focal distance f_m of the image formation optical system A2.

[Equation 7]

$$f = M \cdot f_m$$

When it is considered according to several 7 that the focal distance f of all optical system is fixed, the scale factor M of the hand deflection amendment optical system

A1 makes small the focal distance f_m of the image formation optical system A2, when large, and the scale factor M of the hand deflection amendment optical system A1 needs to enlarge the focal distance f_m of the image formation optical system A2, when small. Then, the scale factor M of this hand deflection amendment optical system A1 is set as the value near 1, as shown in several 8.

[Equation 8]

$$0.8 < |f_{1a} / f_{1b}| < 1.25$$

In several 8, since the scale factor M of the hand deflection amendment optical system A1 will become small too much if the value of a ratio is less than a lower limit 0.8, it will be necessary to enlarge the focal distance f_m of the image formation optical system A2, and enlargement of the image formation optical system A2 will be caused. Moreover, since the scale factor M of the hand deflection amendment optical system A1 will become large too much if the value of a ratio exceeds an upper limit 1.25, it will be necessary to make small the focal distance f_m of the image formation optical system A2, the field angle of the image formation optical system A2 spreads, and amendment of aberration becomes difficult.

[0016] Since the hand deflection amendment optical system A1 is arranged most at a body side, it is desirable to use as the fixed lens I_f by the side of the body which constitutes the hand deflection amendment optical system A1, and to use the lens by the side of an image as a moving lens I_m . There is an advantage that external force with the moving lens I_m impossible for it since the direction which has arranged the moving lens I_m to the image side tends to store the successive range of a moving lens I_m in a lens-barrel which requires precise control is not added. Moreover, it is better to arrange a moving lens I_m to the image side which is not directly touched from the exterior, if it takes into consideration that a lens becomes easy to get damaged, although forming using the lightest possible ingredients (plastics etc.) is desirable as for a moving lens I_m in order to make the migration control easy.

[0017] Afocal conditions are expressed with several 9 when principal point spacing between the fixed lens I_f and a moving lens I_m is set to D_{1a} .

[Equation 9]

$$f_{1a} + f_{1b} - D_{1a} = 0$$

In order to reconcile these several 9 conditions and several 8 conditions, principal point spacing D_{1a} is made as small as possible, namely, it is necessary to oppose the convex of a positive lens, and the concave surface of a negative lens.

[0018] As mentioned above, since this hand deflection amendment optical system A1 is arranged most at the body side, it has the inclination for the diameter of a lens to become large. Therefore, it is better for carrying out migration control of the moving

lens l_m along the direction which intersects perpendicularly to the optical axis of all optical system to lessen configuration number of sheets as much as possible while making thickness of a lens small as much as possible. Moreover, if minor-diameter-izing of the diameter of a lens and the miniaturization of an optical unit are taken into consideration, it is necessary to shorten the focal distance of each lens which constitutes the hand deflection amendment optical system A1 as much as possible.

[0019] In order to make small degradation of the engine performance at the time of carrying out hand deflection amendment as much as possible under such constraint, it becomes important to suppress as small as possible each aberration of the fixed lens l_f and a moving lens l_m . For that purpose, it is desirable to use the fixed lens l_f as a biconcave lens, and to share power with each field by using a moving lens l_m as a biconvex lens.

[0020] By the way, if the afocal hand deflection amendment optical system mentioned above is arranged ahead of image formation optical system, generally negative distortion aberration will increase. In order to amend this negative distortion aberration, it is necessary to specify the radius of curvature and the amount of aspheric surfaces of each field of the fixed lens l_f and a moving lens l_m which constitute the hand deflection amendment optical system A1, and that operation gestalt is shown below. Drawing 3 is the side elevation showing the operation gestalt of the whole configuration of the hand deflection amendment optical system of this invention. Although it is arranged ahead of the image formation optical system A2 of arbitration and this hand deflection amendment optical system A1 can perform hand deflection amendment, it is arranged ahead of 4 group zoom lens Z1 with this operation gestalt.

[0021] Here, in defining the field number i , the radius of curvature r_i of each field, and the lens spacing d_i of each side of each lens, i shall increase every [1] and the radius of curvature r_i of each field in field number $i=5-25$ of each side of 4 group zoom lens Z1, the lens spacing d_i , the refractive index N in d line, and Abbe number ν_d are shown in Table 1 as it progresses to an image side from a body side.

[Table 1]

i	r i	d i	N	ν
1	別 表 参 照			
2				
3				
4				
5	10. 4735	0. 2454		
6	6. 0939	0. 8654	1. 84666	23. 78
7	-141. 1298	0. 0446	1. 62041	60. 34
8	5. 2981	0. 5524		
9	11. 2874	variable	1. 62041	60. 34
10	8. 4710	0. 1561		
11	1. 3982	0. 9536	1. 83400	37. 35
12	-4. 6665	0. 1976		
13	1. 8223	0. 4623	1. 60342	38. 01
14	8. 3807	variable	1. 92286	20. 88
15	STOP	0. 1561		
16	4. 0685	0. 4709		
17	-15. 7475	variable	1. 58913	61. 25
18	2. 7786	0. 1561		
19	1. 4967	1. 0350	1. 84666	23. 78
20	-5. 3164	variable	1. 58913	61. 25
21	INFINITY	0. 3569		
22	INFINITY	0. 4573	1. 51680	64. 20
23	INFINITY	0. 1785	1. 55232	63. 42
24	INFINITY	0. 1673		
25	INFINITY		1. 55671	58. 56

in addition, this operation gestalt -- setting -- focal distance $f=1-14$ of all optical system, and f number $FNO=1:1.65-2.64$ of all optical system -- half--- it is referred to as field angle ω and $2=55.7-4.1$.

[0022] As for INFINITY, radius of curvature shows that it is infinity, i.e., a flat side,

among Table 1, and STOP means the diaphragm. Moreover, the refractive index about air is omitted with the blank in a refractive index N. And it means that variable is a moving lens which a lens moves in the direction of an optical axis. In this operation gestalt, the lens spacing d9, d14, d17, and d20 is variable length, and relation with the focal distance f of all optical system is shown in Table 2.

[Table 2]

d \ f	1. 0000	2. 6110	13. 9543
d9	0. 3729	3. 1512	5. 9233
d14	5. 8675	3. 0955	0. 3234
d17	2. 1235	1. 5684	2. 5161
d20	1. 4566	2. 0130	1. 0650

moreover, field number i= -- each side of the lens of 17 and 20 is made into the aspheric surface configuration, and shows each aspheric surface coefficient A in Table 3. In addition, the degree of an aspheric surface coefficient A is set to 4, 6, and 8.

[Table 3]

i	A_4	A_6	A_8
17	$4. 68492 \times 10^{-3}$	$8. 58483 \times 10^{-4}$	$-2. 79114 \times 10^{-4}$
20	$4. 17919 \times 10^{-3}$	$-4. 44989 \times 10^{-3}$	$1. 55411 \times 10^{-3}$

[0023] First, the 1st operation gestalt of this hand deflection amendment optical system A1 is explained. The radius of curvature r_i of each field in field number $i=1-4$ of each side of fixed lens A1a which constitutes the hand deflection amendment optical system A1, and moving lens A1b, the lens spacing d_i , the refractive index N in d line, and Abbe number ν are shown in Table 4. field number $i=$ -- each side of the lens of 2 and 4 is made into the aspheric surface configuration, and shows each aspheric surface coefficient A in Table 5. In addition, the degree of an aspheric surface coefficient A is set to 4, 6, 8, and 10.

[Table 4]

i	r_i	d_i	N	ν
1	-57.023	0.44	1.492	58
2	9.525	0.32		
3	10.348	1.37	1.492	58
4	-43.043			

[Table 5]

i	A_4	A_6	A_8	A_{10}
2	-0.228×10^{-3}	0.361×10^{-5}	-0.591×10^{-6}	0.227×10^{-7}
4	0.193×10^{-3}	-0.495×10^{-5}	0.663×10^{-6}	-0.224×10^{-7}

[0024] Drawing 4 – drawing 6 are the aberration Figs. of the spherical aberration about the operation gestalt of the above 1st, astigmatism, and distortion aberration, and show a wide angle edge, an intermediate state, and a tele edge, respectively. In addition, in these drawings, the curve of Signs d and g shows the aberration curve concerning d line (wavelength of 587.6nm), and g line (wavelength of 435.8nm), and the curve of Signs M and S shows the aberration curve concerning a meridional image surface and the sagittal image surface.

[0025] Next, the 2nd operation gestalt of this hand deflection amendment optical system A1 is explained. The radius of curvature r_i of each field in field number $i=1-4$ of each side of fixed lens A1a which constitutes the hand deflection amendment optical system A1, and moving lens A1b, the lens spacing d_i , the refractive index N in d line, and Abbe number ν are shown in Table 6. field number $i=$ -- each side of the lens of 2 and 4 is made into the aspheric surface configuration, and shows each aspheric surface coefficient A in Table 7. In addition, the degree of an aspheric surface coefficient A is set to 4, 6, 8, and 10.

[Table 6]

i	r_i	d_i	N	ν
1	-28.796	0.44	1.492	58
2	11.413	0.33		
3	12.150	1.38	1.492	58
4	-27.126			

[Table 7]

i	A_4	A_6	A_8	A_{10}
2	-0.166×10^{-3}	0.255×10^{-5}	-0.369×10^{-6}	0.141×10^{-7}
4	0.144×10^{-3}	-0.303×10^{-5}	0.408×10^{-6}	-0.136×10^{-7}

[0026] Drawing 7 – drawing 9 are the aberration Figs. of the spherical aberration about the operation gestalt of the above 2nd, astigmatism, and distortion aberration, and show a wide angle edge, an intermediate state, and a tele edge, respectively. In addition, in these drawings, the curve of Signs d and g shows the aberration curve concerning d line (wavelength of 587.6nm), and g line (wavelength of 435.8nm), and the curve of Signs M and S shows the aberration curve concerning a meridional image surface and the sagittal image surface.

[0027] Next, the 3rd operation gestalt of this hand deflection amendment optical system A1 is explained. The radius of curvature r_i of each field in field number $i=1-4$ of each side of fixed lens A1a which constitutes the hand deflection amendment optical system A1, and moving lens A1b, the lens spacing d_i , the refractive index N in d line, and Abbe number ν_d are shown in Table 8. field number $i=$ — each side of the lens of 2 and 3 is made into the aspheric surface configuration, and shows each aspheric surface coefficient A in Table 9. In addition, the degree of an aspheric surface coefficient A is set to 4, 6, 8, and 10.

[Table 8]

i	ri	di	N	ν
1	-67.636	0.44	1.492	58
2	9.279	0.32		
3	10.216	1.37	1.492	58
4	-45.331			

[Table 9]

i	A_4	A_6	A_8	A_{10}
2	-0.241×10^{-3}	0.295×10^{-5}	-0.495×10^{-6}	0.182×10^{-7}
4	-0.203×10^{-3}	0.618×10^{-5}	-0.714×10^{-6}	0.242×10^{-7}

[0028] Drawing 10 – drawing 12 are the aberration Figs. of the spherical aberration about the operation gestalt of the above 3rd, astigmatism, and distortion aberration, and show a wide angle edge, an intermediate state, and a tele edge, respectively. In addition, in these drawings, the curve of Signs d and g shows the aberration curve concerning d line (wavelength of 587.6nm), and g line (wavelength of 435.8nm), and the curve of Signs M and S shows the aberration curve concerning a meridional image surface and the sagittal image surface.

[0029] Finally, the 4th operation gestalt of this hand deflection amendment optical system A1 is explained. The radius of curvature ri of each field in field number i=1-4 of each side of fixed lens A1a which constitutes the hand deflection amendment optical

system A1, and moving lens A1b, the lens spacing d_i , the refractive index N in d line, and Abbe number ν are shown in Table 10. field number i = -- each side of the lens of 2 and 3 is made into the aspheric surface configuration, and shows each aspheric surface coefficient A in Table 11. In addition, the degree of an aspheric surface coefficient A is set to 4, 6, 8, and 10.

[Table 10]

i	r_i	d_i	N	ν
1	-30.770	0.44	1.492	58
2	11.128	0.33		
3	11.927	1.38	1.492	58
4	-28.235			

[Table 11]

i	A_4	A_6	A_8	A_{10}
2	-0.173×10^{-8}	0.189×10^{-5}	-0.272×10^{-6}	0.983×10^{-8}
4	-0.157×10^{-8}	0.407×10^{-5}	-0.447×10^{-6}	0.152×10^{-7}

[0030] Drawing 13 - drawing 15 are the aberration Figs. of the spherical aberration about the operation gestalt of the above 4th, astigmatism, and distortion aberration, and show a wide angle edge, an intermediate state, and a tele edge, respectively. In addition, in these drawings, the curve of Signs d and g shows the aberration curve

concerning d line (wavelength of 587.6nm), and g line (wavelength of 435.8nm), and the curve of Signs M and S shows the aberration curve concerning a meridional image surface and the sagittal image surface.

[0031] The result of having summarized each operation gestalt explained above is shown in Table 12. Table 12 Absolute value $|r_2/r_1|$ of the ratio of the radius of curvature r_2 of the 2nd page of biconcave lens A1a of immobilization, and the radius of curvature r_1 of the 1st page, Absolute value $|r_3/r_4|$ of the ratio of the radius of curvature r_3 of the 1st page of movable biconvex lens A1b, and the radius of curvature r_4 of the 2nd page, Absolute value $|\Delta x_1/r_{asp1}|$ of the ratio of the amount Δx_1 of aspheric surfaces of biconcave lens A1a of immobilization (the amount of gaps from the spherical surface), and the paraxial radius of curvature r_{asp1} of the aspheric surface of biconcave lens A1a of immobilization, Absolute value $|\Delta x_2/r_{asp2}|$ of the ratio of amount of aspheric surfaces (amount of gaps from the spherical surface) Δx_2 of movable biconvex lens A1b and the paraxial radius of curvature r_{asp2} of the aspheric surface of movable biconvex lens A1b are shown.

[Table 12]

	$ r_2 / r_1 $	$ r_3 / r_4 $	$ \Delta x_1 / r_{asp1} $	$ \Delta x_2 / r_{asp2} $
実施形態 1	0. 1 7	0. 2 4	$3. 2 \times 10^{-3}$	$0. 6 \times 10^{-3}$
" 2	0. 4 0	0. 4 5	$1. 9 \times 10^{-3}$	$0. 7 \times 10^{-3}$
" 3	0. 1 4	0. 2 3	$3. 5 \times 10^{-3}$	$2. 5 \times 10^{-3}$
" 4	0. 3 6	0. 4 2	$2. 1 \times 10^{-3}$	$1. 6 \times 10^{-3}$

The proper range of each value serves as several 10 – a-13 number from this table 12.

[Equation 10]

[Equation 11]

[Equation 12]

[Equation 13]

[0032] Here, the configuration of the aspheric surface is expressed with several 14 when the direction which intersects the direction of an optical axis perpendicularly with x and it is set to y.

[Equation 14]

$$x = \frac{y^2}{r + \sqrt{r^2 - y^2}} + A_4 y^4 + A_6 y^6 + A_8 y^8 + A_{10} y^{10}$$

Therefore, amount of aspheric surfaces (amount of gaps from the spherical surface) delta xi of biconcave lens A1a and movable biconvex lens A1b of several 12 and immobilization of several 13 is expressed with several 15.

[Equation 15]

$$\Delta x_i = A_4 y^4 + A_6 y^6 + A_8 y^8 + A_{10} y^{10}$$

[0033] Ten above and several 11 specify the relation of the radius of curvature ri of each lens, and several 12 and several 13 specify the relation of amount of aspheric surfaces delta xi of each lens. Distortion aberration can be amended keeping many aberration good by fulfilling these conditions. In addition, even if it deviates from these range, although it is possible, since the yield of spherical aberration and astigmatism increases, it is not desirable [amending distortion aberration].

[0034]

[Effect of the Invention] Distortion aberration can be amended being able to justify image formation optical system easily and keeping many aberration good further according to this invention, while being able to suppress the performance degradation of hand deflection amendment, as stated above.

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] Drawing showing the basic configuration of all optical system including the operation gestalt of the hand deflection amendment optical system of this invention.

[Drawing 2] The principle Fig. about the operation gestalt of the hand deflection amendment optical system shown in drawing 1 in a paraxial field.

[Drawing 3] The side elevation showing the operation gestalt of the whole configuration of the hand deflection amendment optical system of this invention.

[Drawing 4] The aberration Fig. of the spherical aberration in the wide angle edge about the 1st operation gestalt of the hand deflection amendment optical system of this invention, astigmatism, and distortion aberration.

[Drawing 5] The aberration Fig. of the spherical aberration in the intermediate state about the 1st operation gestalt of the hand deflection amendment optical system of this invention, astigmatism, and distortion aberration.

[Drawing 6] The aberration Fig. of the spherical aberration in the tele edge about the 1st operation gestalt of the hand deflection amendment optical system of this invention, astigmatism, and distortion aberration.

[Drawing 7] The aberration Fig. of the spherical aberration in the wide angle edge about the 2nd operation gestalt of the hand deflection amendment optical system of this invention, astigmatism, and distortion aberration.—

[Drawing 8] The aberration Fig. of the spherical aberration in the intermediate state about the 2nd operation gestalt of the hand deflection amendment optical system of this invention, astigmatism, and distortion aberration.

[Drawing 9] The aberration Fig. of the spherical aberration in the tele edge about the 2nd operation gestalt of the hand deflection amendment optical system of this invention, astigmatism, and distortion aberration.

[Drawing 10] The aberration Fig. of the spherical aberration in the wide angle edge about the 3rd operation gestalt of the hand deflection amendment optical system of this invention, astigmatism, and distortion aberration.

[Drawing 11] The aberration Fig. of the spherical aberration in the intermediate state about the 3rd operation gestalt of the hand deflection amendment optical system of this invention, astigmatism, and distortion aberration.

[Drawing 12] The aberration Fig. of the spherical aberration in the tele edge about the 3rd operation gestalt of the hand deflection amendment optical system of this invention, astigmatism, and distortion aberration.

[Drawing 13] The aberration Fig. of the spherical aberration in the wide angle edge about the 4th operation gestalt of the hand deflection amendment optical system of this invention, astigmatism, and distortion aberration.

[Drawing 14] The aberration Fig. of the spherical aberration in the intermediate state about the 4th operation gestalt of the hand deflection amendment optical system of this invention, astigmatism, and distortion aberration.

[Drawing 15] The aberration Fig. of the spherical aberration in the tele edge about the 4th operation gestalt of the hand deflection amendment optical system of this invention, astigmatism, and distortion aberration.

[Description of Notations]

A1 [... A moving lens, LD / ... A lens mechanical component, If / ... A fixed lens, Im / ... Moving lens] ... Hand deflection amendment optical system, A2 ... Image formation optical system, A1a ... A fixed lens, A1b